Reducing Environmental Impacts: Aluminium Recycling

**Case Study**

# Crediting Aluminium Recycling in LCA by Demand or by Disposal*

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**DOI:** http://dx.doi.org/10.1065/lca2007.06.348

**Please cite this paper as:** Frees N (2008): Crediting Aluminium Recycling in LCA by Demand or by Disposal. Int J LCA 13 (3) 212–218

**Abstract**

**Background, Aim and Scope.** By using recycled aluminium or by disposing used aluminium products for recycling, it is normal LCA practice to give a credit for the avoided production of primary or recycled aluminium. Lately, consequential approaches have been suggested to qualify and quantify this credit in terms of market mechanisms. Depending on supply, demand and price elasticity of primary products and scrap products, a mixed share of primary and recycled material may be credited. Aluminium, having high energy consumption for its primary production and low energy consumption for recycling, is very sensitive concerning whether production of primary or recycled aluminium is avoided. This paper includes presentations of aluminium products which are typically made from primary and from recycled aluminium. This is essential concerning which production may be avoided. Examples of market mechanism parameters of aluminium for consequential LCA are given.

**Methods.** A survey of aluminium products manufacturing is made to determine which products are made from primary and which from recycled aluminium. To estimate the price elasticity, statistics of supply and prices of primary aluminium and aluminium scrap are compiled and papers concerning supply, demand and price elasticity of aluminium are summarised. The parameters are suggested for performing consequential LCA.

**Results.** The available amount of aluminium scrap covers only approx. 30–40% of the demand for aluminium, and hence approx. 60–70% of the demand is inevitably made from primary aluminium. Open loop recycled aluminium is primarily used for casting alloys, but closed loop recycling exists, for example, for aluminium cans. The open loop market for low-alloyed aluminium sheets and profiles is primarily covered by primary aluminium. It is therefore of no use to demand recycled aluminium of these qualities, but if the products are recycled after use, they should be credited for the avoided production.

**Discussion.** The supply price elasticity of aluminium scrap is estimated to be rather inelastic, and the avoided production will hence primarily be of primary aluminium. This is in contradiction to a default recommendation for consequential LCA saying that a 50/50 share of primary and recycled material is avoided by recycling most materials.

**Conclusions.** An important conclusion of the paper is that, given the inelastic price elasticity of aluminium scrap, it is production of primary aluminium which is avoided by recycling. This conclusion is actually in agreement with the traditional systems expansion, which has been put under question by consequential LCA. Because primary aluminium is avoided by recycling, a credit of avoided production of primary aluminium should be given when a used product is recycled. Hence, a credit should not be given when demanding recycled aluminium, or aluminium with a certain recycled content.

**Recommendations and Perspectives.** It is recommended that aluminium is considered price inelastic in consequential LCA, and that avoided production of primary aluminium is credited when recycling a used aluminium product. Avoiding primary material by recycling has great perspectives for aluminium with its high energy consumption for primary production and low energy consumption for recycling.

**Keywords:** Aluminium recycling; avoided production; consequential LCA; market-based LCA; system expansion

## Introduction

The environmental soundness of aluminium is often questioned because of the large consumption of energy and use of problematic auxiliaries for the primary production. Other factors for which the environmental profile of aluminium is especially sensitive are processing and net-consumption of the material. The environmental profile of products made from aluminium, or other materials, is defined by:

1. The amount of material used for providing a function in comparison with other materials or with a reference,
2. environmental characteristics of manufacturing processes applied to the material, and
3. account for recycling and avoided production of metal, which is saved by recycling.

In this paper, point 3 is addressed, but a few comments should be made to point 1 and 2: The manufacturing and amount of a material used for serving a function depends on technical properties of the material. For technical application, aluminium is characterised by a high strength to weight ratio, easy processing and little demand for finishing processes.

The high strength to weight ratio means that it is sufficient to use relatively small weight amounts of aluminium compared with other technical materials, e.g. steel, wood or plastics. In the processing of aluminium it is possible to apply so-called near-net shaping in aluminium castings and forged products where almost no material is wasted and only little finishing is needed. Very good corrosion resistance can be achieved by anodising, which does not use large amounts of energy and problematic chemicals compared to other types of surface treatments.

To get an overview of the environmental soundness of different materials, it is recommendable to take the holistic

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approach obtained via comparable life cycle assessments. However, in an LCA it is not an easy task to deal with the recycling of a product as illustrated by the large number of papers on allocation and system expansion – e.g. Klöpffer (1996), Ekvall and Tillman (1997), Ekvall (2000), Cederberg C and Stadig M (2003), Ekvall and Weidema (2004).

The aim of this paper is to establish guidelines for how to deal with recycling of aluminium in a consequential LCA. For doing this, market based consequential LCA will have to be discussed and its main parameters, price elasticity of recycling supply and demand will have to be defined. Then it must be discussed which types of products that are typically made from primary and from recycled aluminium.

Section 1 gives a presentation of aluminium recycling and market-based consequential LCA. Section 2 discusses and defines the main parameters for aluminium which are needed to perform a market-based consequential LCA and discusses the use of primary and recycled aluminium in products. Section 3 suggests guidelines for handling recycling of typical aluminium products in an LCA and Section 4 and 5 finally conclude and provide perspectives of the paper.

## 1 Methods

### 1.1 Aluminium recycling in LCA

**Accounting for aluminium recycling.** In contrast to the large consumption of energy and use of potentially hazardous auxiliaries for the primary production, aluminium recycling is characterised by low energy consumption (Boustead 2000) and is considered rather harmless. Therefore, accounting for recycling is crucial for aluminium. Two viewpoints exist on how to do this: 1) The amount of the used material which is collected and recycled should be accounted for or 2) The amount of recycled material used in a product should be accounted for – i.e. the so called recycled content in a product.

The argument for 1) is that if you make a product from recycled material and/or primary material, and this product is not collected and recycled after use, primary material will have to be produced to replace the material that is not recycled. By recycling, a credit is given for avoided production of primary aluminium which encourages producers to easily facilitate reuse or recycling in the design of products. The argument is used for materials for which there is a growing demand (increasing market), which is the case for aluminium as discussed in Section 2.1. This argument for system expansion is widely used within LCA, but it has been criticised that a manufacturer of an aluminium product will not be credited for using recycled aluminium, and this is the background for viewpoint 2). Furthermore, viewpoint 1) does not take into account that part of the recycled aluminium may replace recycled and not primary aluminium.

A substantial drawback to viewpoint 2) is that the average recycling level of aluminium – approx. 40% of the aluminium consumption on a world basis – does not tell anything about to which degree a product is recycled after use. Even if all aluminium is recycled after use, the produced amount could not cover the world's demand, because this demand has grown remarkably since the recycled aluminium was originally produced (typically 20 to 30 years ago). In practice, aluminium is recycled into qualities that can most easily be made from re-melted scrap like, for example, casting alloys as discussed in Section 2.2 and hence other qualities are made from primary aluminium.

A way to consider both the collection of aluminium for recycling and the recycled content in a product is market based consequential LCA which has been presented in different papers (Ekvall 2000, Ekvall and Weidema 2004) and discussed here for the example of aluminium recycling.

### 1.2 Recycling in consequential LCA

Ekvall (2000) suggests a conceptual model, which shows how open loop recycling of a material affects the market of other recycled material and of primary material in terms of supply and demand for recovered material. The model, shown in **Fig. 1**, illustrates that recycling of a specific prod-

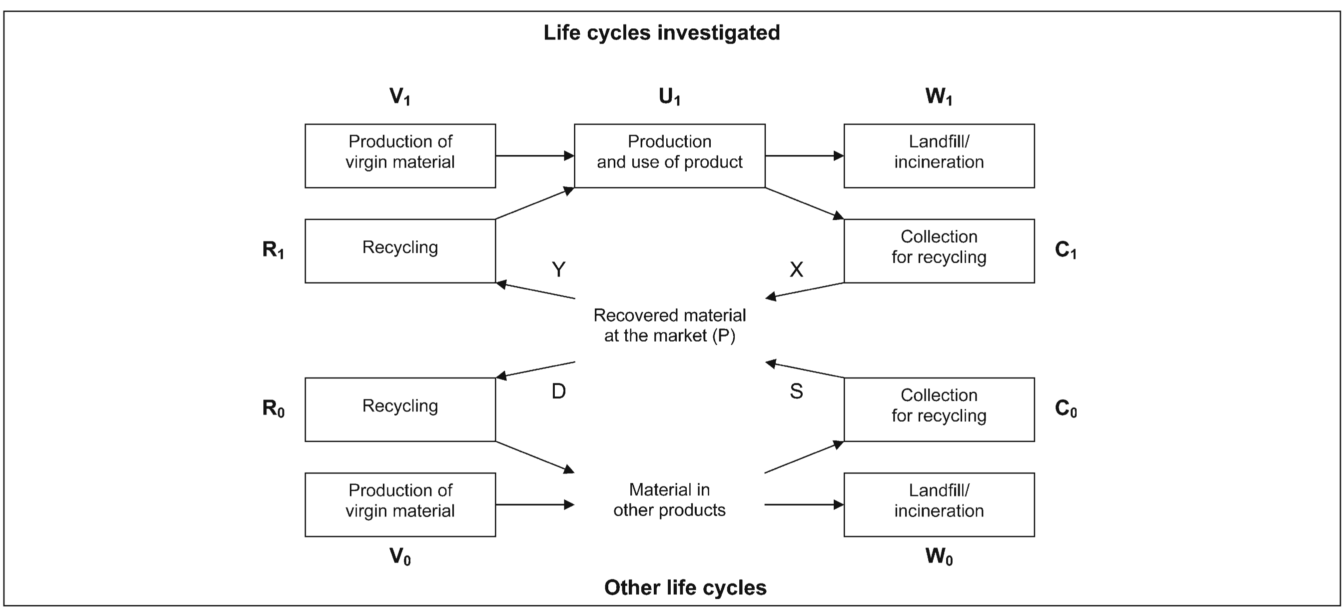


**Fig. 1:** Conceptual model of the life cycle investigated as connected to other life cycles through the market for recycled material

uct may influence not only the market of virgin materials for the product (the life cycle of the product), but also other and larger markets (life cycles of other similar products), maybe globally. Then, recycling of the product may lead to avoided production of primary material or avoided production of recycled material in another life cycle. According to the model, the avoided production depends on the price elasticity of supply of collected scrap for recycling and on the price elasticity of demand for the recycled material in question – i.e. how sensitive the producer is to the price of supply and demand.

The letter symbols U, V, R and W represent unit processes the meaning of which appears in Fig. 1. Index 1 represents the life cycle of the investigated product and 0 represents the life cycle of other products. The letter symbols X, Y, S and D are:

X Collected amount of scrap material for recovery from the investigated product,
Y amount of recovered material used for recycling within the life cycle of the investigated product,
S collected amount or supply of scrap material for recovery for all other products in society, and
D amount or demand of recovered material used for recycling within other products' life cycle.

The main idea of Ekvall (2000) is that a change in the amount of used material (scrap) collected for recycling in the product life cycle investigated ($\Delta X$) affects the collection for recycling in other life cycles ($\Delta S$) and/or the use of recycled materials ($\Delta Y + \Delta D$), and that the affect can be estimated by the price elasticity of supply and demand of used material collected for recycling. It is assumed that the recycled material affects primary or recycled material of the same type and not a completely different material (i.e. that recycled aluminium replaces aluminium).

The price elasticity of supply is generally defined as:

$$\eta_S = \frac{\textit{percent change of supply}}{\textit{percent change of price}} \tag{1}$$

or, provided that X << S:

$$\eta_S = \frac{\Delta S / S}{\Delta P / P} \tag{2}$$

where $P$ is the price of recovered material.

The price elasticity of demand is generally defined as:

$$\eta_D = \frac{\textit{percent change of demand}}{\textit{percent change of price}} \tag{3}$$

or, provided that Y << D:

$$\eta_D = \frac{\Delta D / D}{\Delta P / P} \tag{4}$$

If the amount of material collected for recycling in the product life cycle investigated is changed by $\Delta X$, the effects on the demand ($\Delta D$) of or supply ($\Delta S$) from other life cycles can be calculated from (Ekvall 2000):

$$\Delta D_X = \frac{\Delta X\, \eta_D}{\eta_D - \eta_S} \tag{5}$$

$$\Delta S_X = \frac{\Delta X\, \eta_S}{\eta_D - \eta_S} \tag{6}$$

Vice versa, if the amount of recycled material used in the product life cycle investigated is changed by $\Delta Y$, the effects on the demand ($\Delta D$) of or supply ($\Delta S$) from other life cycles can be calculated from (Ekvall and Weidema 2004):

$$\Delta D_Y = -\frac{\Delta Y\, \eta_D}{\eta_D - \eta_S} \tag{7}$$

$$\Delta S_Y = -\frac{\Delta Y\, \eta_S}{\eta_D - \eta_S} \tag{8}$$

In absolute values, price elasticity may be qualified as follows:

$|\eta| < 1$ represents a price inelastic situation. If $\eta$ is 0 it is completely inelastic, and the supply or demand is not affected by a change in the price

$|\eta| = 1$ represents a neutral price elasticity, where a direct relationship exists between supply and demand and change in price

$|\eta| > 1$ represents a price elastic situation where supply or demand is strongly affected by a change in price

Estimation of price elasticity may be difficult and very uncertain. Furthermore, the price elasticity may vary with the time horizon of a study. Ekvall and Weidema (2004) give an example from literature in which the price elasticity of supply of old newspapers ranges from 0.06 to 1.7. Such a range can of course lead to any conclusion of a study. This is not to say that the concept of price elasticity should not be used, because no other very good methods have been proposed at the moment to deal with recycling, for example, dealing with a decreasing market, in which recycled aluminium to a smaller or larger extend may replace other recycled aluminium.

To overcome the difficult estimation of price elasticity and to counter misleading results, Ekvall and Weidema (2004) suggest the following simplified approach:

1) Use default values for price elasticities of scrap based on literature to be inserted in the equations above. Ekvall (2000) summarises a number of values that are all rather uncertain.
2) Assume that the supply and demand are equally price elastic ($\eta_S = -\eta_D$). This leads to a 50/50 approximation where 50% of a recycled material replaces recycled material from other life cycles and 50% replaces primary material.

3) Assume that the supply is completely price inelastic ($\eta_S = 0$). This leads to the approximation that recycled material replaces 100% primary material.
4) Assume that the demand is completely price inelastic ($\eta_D = 0$). This leads to the approximation that recycled material replaces 100% recycled material from other life cycles
5) Develop multiple scenarios based on different choices among the assumptions above – e.g. a reference scenario and a number of sensitivity scenarios.

In the case for old newspaper mentioned before, one could choose option 2, which may possibly not provide the precise answer but, on the other hand, it does not lead to a totally wrong conclusion.

LCAs of materials, for which the difference between the environmental profile of primary and recycled material is not very large, are not particularly sensitive to the range of the price elasticity. For aluminium, where the environmental difference between primary and recycled material is large, conclusions based on a wide range of price elasticities are not acceptable. For aluminium, the price elasticity of supply and demand will thus have to be estimated rather precisely or it should be justified whether one of the approaches ($\eta_S = -\eta_D$), ($\eta_S = 0$) or ($\eta_D = 0$) could be followed, which is basically the aim of this paper.

## 2 Results

### 2.1 Price elasticity of recycled aluminium

In economy, it is a general assumption that products, which can easily be replaced by competitive products, are price elastic, and that products that are difficult or impossible to replace are price inelastic.

Few investigations exist of the price elasticity of a supply of aluminium scrap for recycling or of demand for recycled aluminium. Palmer et al. (1997) report a study of recycled aluminium packaging for which ($\eta_S = 1.1$) and ($\eta_D = -0.8$). Note that the sign of the price elasticity of demand is always negative. These figures indicate that the price elasticity of recycled aluminium is close to neutral and that the approach of $\eta$ ($\eta_S = -\eta_D$) could be used, meaning that the recycled aluminium packaging replaces primary and recycled aluminium in equal amounts. However, the majority of the aluminium packaging investigated by Palmer et al. consists of cans, which are characterised by a high share of closed loop recycling, and that recycled aluminium will then replace recycled aluminium within the same life cycle. Aluminium cans with their high share of closed loop recycling is not representative for aluminium recycling in general. Furthermore, the estimated price elasticities represent the situation in the mid 1980s and may no longer be representative.

Blomberg (2000) has investigated the supply and demand price elasticities of recycled aluminium casting alloys and found the supply price to be inelastic. According to Blomberg, the supply price elasticity is 0.2, which means that approach 3) of Section 1.2, ($\eta_S = 0$), could be used with the result that recycled aluminium replaces 100% primary aluminium. As discussed in Section 3, casting alloys are representative for open loop aluminium recycling.

The price of aluminium is determined on the London Metal exchange for defined alloys. According to the European Aluminium Association (2004a), the alloys are normally made from primary metal, but they could also come from recycled aluminium. Crucial is if an alloy is composed according to a standardised specification and not whether it is virgin or recycled. The price for scrap depends on the quality of the scrap. For example, a known and uncontaminated alloy constitutes a good scrap quality and mixed scrap contaminated with other materials constitutes a poor scrap quality, which requires more processing. Examples of scrap prices are shown in **Table 1.**

Besides the quality of the scrap, the scrap prices are linked to the price of primary metal. This is because the recycling plants have a defined cost margin they can operate within between the price they get for their products, which is defined by the price of primary metal of same quality, and what they have to pay for the scrap. Blomberg (2000) and Hess et al. (2001) confirm the assumption that aluminium scrap prices are linked to the price of primary aluminium. The development of primary and scrap aluminium prices in

**Table 1:** Aluminium production and prices

| | Western Countries production, kton | | | | | World, kton | Prices, £/ton | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Virgin | % | Recycled | % | In all | Primary production | Primary 99,5% Ingot | New scrap pure cuttings | Old scrap cast |
| 1973 | | | | | | 12,837 | 244 | | |
| 1978 | | | | | | 14,769 | 689 | | |
| 1983 | | | | | | 15,084 | 943 | | |
| 1988 | | | | | | 18,584 | 1,100 | | |
| 1993 | 15,066 | 71% | 6,256 | 29% | 21,322 | 19,739 | 760 | | |
| 1998 | 16,592 | 68% | 7,829 | 32% | 24,421 | 22,626 | 830 | 768 | 577 |
| 2000 | 17,476 | 67% | 8,456 | 33% | 25,932 | 24,280 | 1,018 | 905 | 656 |
| 2001 | 16,623 | 68% | 7,886 | 32% | 24,509 | 24,084 | 999 | 926 | 656 |
| 2002 | 17,216 | 69% | 7,911 | 31% | 25,127 | 25,746 | 904 | 822 | 678 |
| 2003 | 17,587 | 69% | 7,918 | 31% | 25,505 | 27,497 | 872 | 791 | 678 |

**Note:** No information of recycled production in China and India, see text
**Sources:** Metal Statistics 2004, London Metal Exchange 2005, EAA 2006

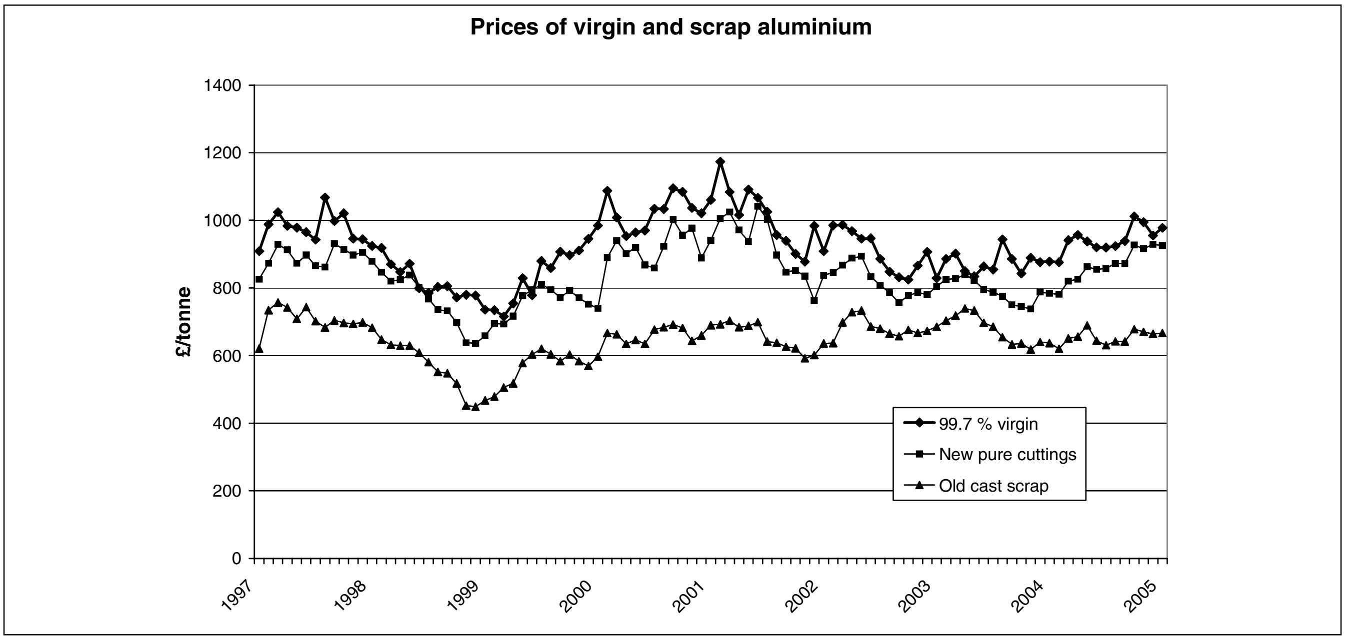


**Fig. 2:** Relationship between prices for primary aluminium, old scrap and new scrap

recent years is provided in **Fig. 2**, based on information in Metal Bulletin (2006) and London Metal Exchange (2005).

Aluminium statistics show that the consumption of both primary and recycled aluminium is increasing. World Bureau of Metal Statistics (2004) provide data for Western Countries' primary and recycled aluminium production, and almost complete data for the World's primary production (see Table 1). The World's recycled production is uncertain because important countries like China and India are missing in the statistics of recycled aluminium. Compared to the Western Countries' 7,911 ktons (see Table 1), China produced 1,500 ktons recycled aluminium in 2002 (TDC 2005) with an expected growth to 2,100 ktons in 2005 and 3,050 ktons in 2010. China has a large import of aluminium scrap from Western Countries which may be a reason for the recent stagnation in the recycled production in these countries. India is not yet as important a player as China but will expectedly follow the same trend (TIFAC 1996). Both countries are characterised by many small and uncontrolled collectors and remelters which may be the reason for the uncertain statistics. However, scrap collection will be regulated in the future, and large remelters are expected to enter the market.

The aluminium, which is recycled today, was produced maybe 20–30 years ago on average and, because the production of aluminium was smaller at that time than today, the amount of aluminium scrap is insufficient to satisfy the market demand. This insufficiency is clearly demonstrated by the situation in China and India (TDC 2005, TIFAC 1996). The sparse supply of aluminium scrap, together with the fact that the price of aluminium scrap is determined by the price of primary aluminium, confirms the result of Blomberg (2000) that the supply price of recycled aluminium is inelastic.

Finally, aluminium scrap and primary aluminium cannot easily replace each other on the input side, because the production of aluminium is specialised in aluminium refiners and remelters, on the one hand, who make aluminium from scrap only, and in primary manufacturers, on the other hand, who make aluminium from the primary resource bauxite. This means that the makers of recycled aluminium cannot substitute their 'raw material' and this too indicates that the supply price of aluminium scrap is inelastic on the open loop market. Many aluminium companies own both primary and recycling plants, and an increase in scrap price could therefore lead to a decrease in production of recycled aluminium and an increase in primary production, but this is not a likely scenario since the economy in making recycled aluminium is basically good, and the aluminium scrap prices follow the prices of primary aluminium, thus leaving a margin for profitable production, as discussed before, even though the profitability for the Western World recycling has come under pressure from the Chinese and Indian competition.

On the output side, primary and recycled aluminium replace each other in most applications, so the demand price elasticity may be more or less elastic. The price of products made from recycled aluminium follows the price of similar products made from primary aluminium, indicating that the price of recycled aluminium is indeed elastic. However, a decrease in price of recycled aluminium will not lead to a significantly increased production because of the shortage in scrap supply discussed before and this indicates that the demand price elasticity is limited. Nevertheless, the assumption that $\eta_D = 0$ does not seem reasonable.

### 2.2 Use of primary and recycled aluminium

In order to establish further background for discussion and guidelines, this section gives an impression of the aluminium market – i.e. which products are usually made from recycled and which from primary aluminium and which products may be characterised by open loop and which by closed loop recycling.

As a raw material for manufacturing, aluminium is classified into three product groups: Casting alloys, rolled aluminium and extruded aluminium. Rolled and extruded aluminium are also called wrought aluminium. Casting alloys usually contain a high amount (approx. 12%) of silicon and the amount of other alloying elements may also be relatively high compared to wrought aluminium, which is low alloyed. Because casting aluminium is high alloyed, recycled casting alloys are not as sensitive to the scrap source as wrought aluminium is.

Main sectors for aluminium use are: Transport (36%), building (26%), packaging (17%) and engineering (14%). The brackets show percentage of total Western Europe tonnage (European Aluminium Association, 2005). The raw materials are used for different applications. For example, a majority (74%) of casting alloys is used within the transport sector, and a high share (39%) of extruded aluminium is used within the building sector. Rolled aluminium is widely used for packaging (foils and rigid), but also, for instance, for the transport and building sectors.

On the market for semi-manufactured products - i.e. on the demand side – primary and recycled aluminium may easily replace each other within each of the three product groups. Actually, it is usually impossible to trace whether a product is made from primary or from recycled aluminium, and the amount of recycled material used in a product - the recycled content – then becomes meaningless.

On the supply side, primary production and recycled production cannot easily replace each other as discussed previously. It appears from **Fig. 3** that refiners – i.e. producers of recycled aluminium casting alloys – use a high share of old (end use) or unknown scrap, whereas remelters – i.e. producers of recycled wrought (or semi-manufactured) aluminium – use a high share of new (production) scrap. It also appears that a relatively high share of the remelters uses tolled scrap – i.e. products imposed a fee for recycling like, for example, cans.

**Fig. 3** clearly indicates that aluminium is recycled into qualities that can most easily be made, which is casting alloys from old scrap and wrought products from known scrap qualities like new or tolled scrap. The annual demand for casting alloys in Western Europe is approx. 2.6 million tons which could be covered by the scrap intake to European aluminium refiners if import/export and waste is not accounted for. The European annual production (2003) of wrought aluminium is approx. 6.8 million tons, of which 1.6 million tons may be produced from re-melted scrap. Then, 5.2 million tons will have to be produced from primary aluminium or imported. The primary European aluminium production in 2003 was 4.15 million tons and the net import was 2.4 million tons, in all 6.55 million tons (European Aluminium Association, 2004b and 2005). The difference between 6.55 million tons produced and imported primary aluminium and 5.2 million tons needed for wrought production is used for production of other aluminium products (e.g. oxidation aluminium, powders and some casting alloys) and for covering production waste.

Refiners use a very small share of tolled aluminium (8%) and the majority of the scrap input for refiners is purchased or not identified. The later are bought on the scrap market and then casting alloys are representative for open loop aluminium recycling.

Remelters use a relatively high share (43%) of tolled scrap. Tolled scrap is characterised by closed loop recycling.

## 3 Discussion and Guidelines

This section synthesises the previous sections into guidelines of how aluminium products should be credited when recycled.

One should first and foremost distinguish between closed and open loop recycling.

Closed loop recycling is primarily characteristic for tolled products (e.g. cans) that are recycled by refiners into wrought (semi-manufactured) products, which are again used for tolled products of their original function. Palmer et al. (1997) has found the supply and demand price elasticities for cans of ($\eta_S$ = 1.1) and ($\eta_D$ = –0.8). This indicates, that recycled cans replaces recycled and primary aluminium in equal amounts, but closed loop recycling is a special case for which the conceptual model of Fig. 1 was not intended. If one assumes that closed loop recycling does not affect other markets, it could be handled by a simple mass balance of which recycled material replaces recycled and primary material entering the mass balance for substituting materials lost from the system.

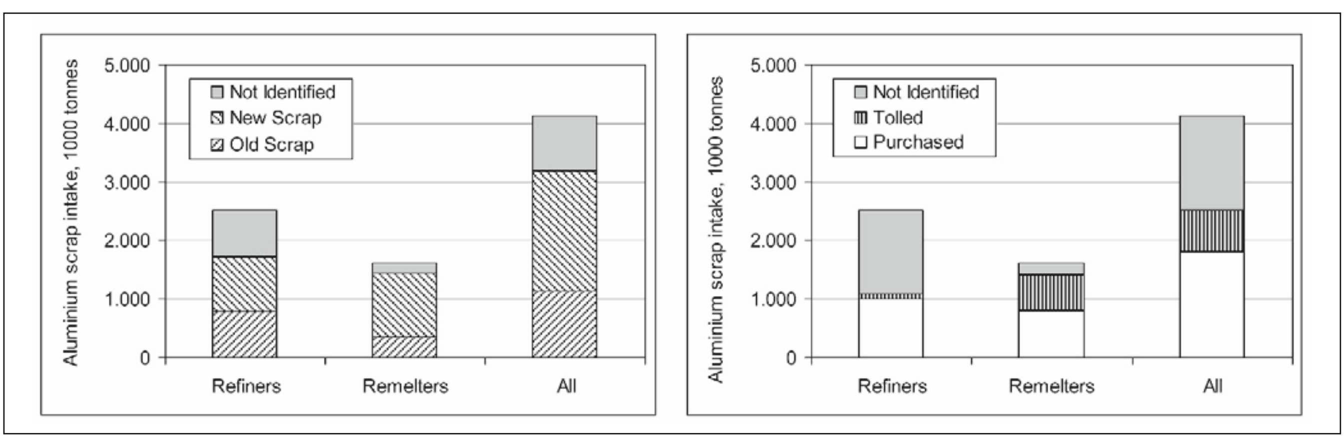


**Fig. 3:** Western Europe production of recycled aluminium shown as shares between old and new scrap and tolled and purchased scrap (European Aluminium Association, 2005)

Considering open loop recycling of aluminium, the supply price of aluminium scrap is inelastic and therefore, according to the conceptual model discussed in Section 1.2, recycled will replace virgin aluminium. This is the general case and exceptions will be extreme cases, for example if limits or restriction of lead or iron in the scrap forces one to dilute with pure and maybe primary aluminium.

The aluminium scrap entering open loop recycling could be new scrap from production waste or old scrap from used products. A large part of the scrap is unknown, but is most likely old scrap because the price of old scrap is lower than the price of new scrap.

Because casting alloys have a high silicon content, it will involve refiners, which will again produce casting alloys. Wrought alloys enter remelters as well as refiners. It is first and foremost new scrap which is re-melted, because new scrap is usually made up of alloys of a known content.

Casting alloys are primarily used in the transport sector (e.g. engines, gear housing). Products made from wrought alloys are typically used in the building and engineering sectors, but also in the transport sector. The product categories mentioned are typical examples for which the aluminium of the products when recycled replace primary aluminium, and are therefore given credit for the avoided production of the primary aluminium.

For several reasons, it is of no use to count for or ask for recycled content in a product. One major reason is that in order to satisfy the demand for aluminium, a large part of the aluminium production must be made from primary aluminium which is recycled after use. Another reason is that, for many specifications of aluminium, one does not distinguish whether it comes from virgin or recycled aluminium.

## 4 Conclusions

The major conclusion of the paper is that the price of aluminium scrap is rather inelastic, and that primary aluminium is then avoided by recycling. This conclusion is actually in agreement with the traditional way of expanding LCA systems, but has been put under question by consequential LCA (Ekvall 2000, Ekvall and Weidema 2004). Another conclusion is that the crediting of avoided production of primary aluminium should be given by recycling of the used product, and not by demanding recycled aluminium for a new product. Therefore, the concept of recycled content becomes meaningless.

The available amount of aluminium scrap covers only approx. 30–40% of the demand for aluminium, and then approx. 60–70% of the demand is inevitably made from primary aluminium. The exact figures are difficult to determine because of the rather unknown amount of recycling in China and India. However, this share is different for casting alloys and for wrought alloys. Because casting alloys are most easily made from scrap, the majority of casting alloys are recycled, whereas maybe only 20–25% of wrought aluminium is made from recycled aluminium, primarily because of a lack of scrap. Open loop recycled aluminium is primarily used for casting alloys, whereas 43% of the European recycling of wrought products is closed loop, e.g. of aluminium cans.

## 5 Recommendations and Perspectives

Crediting primary aluminium for recycled aluminium is of crucial importance for this material, in particular since the energy consumption for making primary aluminium is much larger than the energy consumption for recycling aluminium. Therefore, it is important that the price elasticities are representative if these are used as a basis for crediting the recycling of aluminium. The conclusion of this paper recommends that aluminium scrap be considered price inelastic and, hence, avoided production of primary aluminium is credited by recycling. The perspective of this recommendation is an incitement in LCA to recycle used aluminium products disregarding their type or origin.

**Acknowledgements.** The European Aluminium Association (EAA) is acknowledged for their support to this study.

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Received: June 20th, 2007
Accepted: June 25th, 2007
**OnlineFirst: June 26th, 2007**